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FARMERS' BULLETIN No. 127.

IMPORTANT INSECTICIDES.

DIRECTIONS FOR THEIR PREPARATION AND USE.

[SECOND REVISION.]

BY

C. L. MARLATT, M. S.,

ENTOMOLOGIST AND ASSISTANT CHIEF, BUREAU OF ENTOMOLOGY.



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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY,
Washington, D. C., March 2, 1908.

SIR: I have the honor to transmit herewith a second revision of Farmers' Bulletin No. 127, on insecticides. The five years that have elapsed since the last revision of this publication have brought some important additions to our knowledge of insecticides and have necessitated some changes of old formulas. These additions and corrections have been incorporated in this revision. As stated in the letter of transmittal to the first edition, this bulletin supplants Farmers' Bulletin No. 19, prepared in 1894 by Mr. C. L. Marlatt, then First Assistant Entomologist. The latter publication, having gone through four slightly revised editions, was in large part rewritten by Mr. Marlatt early in 1901 and issued under the new number to take the place of the older publication.

Respectfully,

L. O. HOWARD,
Entomologist and Chief of Bureau.

HON. JAMES WILSON,
Secretary of Agriculture.

CONTENTS.

	Page.
Introductory.....	5
Relation of food habits to remedies.....	5
Injury from biting insects.....	5
Injury from sucking insects.....	6
Groups subject to special treatment.....	7
Insecticides for external biting insects (food poisons).....	7
The arsenicals.....	7
Paris green.....	8
Copper arsenite.....	8
Arsenite of lime.....	9
London purple.....	9
Arsenate of lead.....	9
General considerations.....	10
How to apply arsenicals.....	10
The wet method.....	11
The dry method.....	11
Poisoned bait.....	12
Time to spray for biting insects.....	13
Care in the use of arsenicals.....	14
Insecticides for external sucking insects (contact poisons).....	14
Soaps as insecticides.....	15
Pyrethrum, or insect powder.....	16
Tobacco decoction.....	16
Sulphur.....	16
Petroleum oils.....	17
Pure kerosene treatment.....	18
The crude petroleum treatment.....	19
The oil-water treatment.....	19
Kerosene emulsion (soap formula).....	20
Kerosene emulsion (milk formula).....	21
The distillate emulsion.....	21
How to use the emulsions.....	22
Cautions regarding use of oil washes.....	22
Miscible oils.....	23
The resin wash.....	23
The lime-sulphur wash.....	24
Composition and preparation.....	25
Directions for use.....	26
Range of usefulness.....	26
Time to spray for sucking insects.....	27

	Page.
Dusting and spraying apparatus	28
Powder distributors	28
Liquid sprayers	28
The barrel pump	29
Tank outfits	29
Geared sprayers	29
Gas-pressure sprayers	29
Hose, nozzle, and agitator	30
Selection of spraying outfit	30
Directions for spraying	31
Hydrocyanic-acid gas treatment	31
Fumigation of nursery stock	32
Orchard fumigation	33
Amounts of chemicals to use	33
General directions	35
Construction and handling of tents	36
Bisulphid of carbon vapor	38
Remedies for subterranean insects	38
Hot water	39
Tobacco dust	39
Kerosene emulsion and resin wash	40
Potash fertilizers	41
Bisulphid of carbon	41
Submersion	42
Remedies for insects affecting grain and other stored products	42
General methods of treatment	42
Bisulphid of carbon	43
Character and method of application	43
Caution	44
Sulphur dioxid	44
General considerations on the control of insects	45
Advantage of prompt treatment	45
Killing insects as a profession	45
Determination of the result of treatment	46
Control of insects by cultural methods	47
The profit in remedial measures	48

ILLUSTRATIONS.

	Page.
Fig. 1. Illustrating the different classes of biting insects	6
2. Illustrating the different classes of sucking insects	6
3. Barrel spray pump	28
4. Power sprayer at work in apple orchard	29
5. Vermorel spray nozzle	30
6. Tenting trees for gas treatment, San Diego, Cal.	32
7. Method of hoisting sheet tent	36

IMPORTANT INSECTICIDES: DIRECTIONS FOR THEIR PREPARATION AND USE.

INTRODUCTORY.

Without going minutely into the field of remedies and preventives for insect depredations it is proposed to give in this bulletin brief directions concerning a few of the insecticide agents having the widest range and attended with the greatest usefulness, economy, and ease of application. These are not covered by patents, and in general it is true that the patented articles are inferior, many of the better of them being in fact merely more or less close imitations of the standard substances and compounds hereinafter described. Only such brief references to food and other habits of insects will be included as are necessary to illustrate the principles underlying the use of the several insecticide agents.

RELATION OF FOOD HABITS TO REMEDIES.

For the intelligent and practical employment of insecticides it is necessary to comprehend the nature and method of injury commonly due to insects. Omitting for the present purpose the exceptional forms of injury which necessitate peculiar methods of treatment, the great mass of the harm to growing plants from the attacks of insects falls under two principal heads based on distinct principles of food economy, viz, whether the insect is a biting (mandibulate) or a sucking (haustellate) species. Each group involves a special system of treatment.

INJURY FROM BITING INSECTS.

The biting or gnawing insects are those which actually masticate and swallow some portion of the solid substance of the plant, as the wood, bark, leaves, flowers, or fruit. They include the majority of the injurious larvæ, many beetles, and the grasshoppers. (See fig. 1.)

For these insects direct poisons, such as the arsenicals, which may be safely applied to the leaves or other parts of the plant attacked,

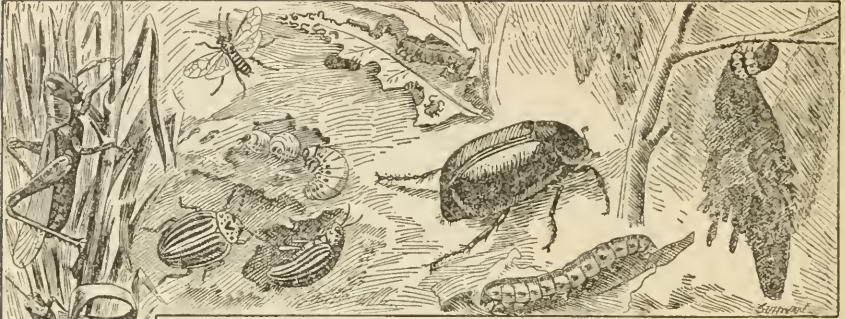


FIG. 1.—Illustrating the different classes of biting insects. All natural size. (Author's illustration.)

and which will be swallowed by the insect with its food, furnish the surest and simplest remedy, and should always be employed, except where the parts treated are themselves to be shortly used for the food of animals or of man.

INJURY FROM SUCKING INSECTS.

The sucking insects are those which injure plants by the gradual extraction of the juices from the bark, leaves, or fruit, and include the plant-bugs, aphides, scale insects, thrips, and plant-feeding mites. These insects possess, instead of biting jaws, sucking beaks or bristles, which are thrust down through the outer layers of the bark or leaves

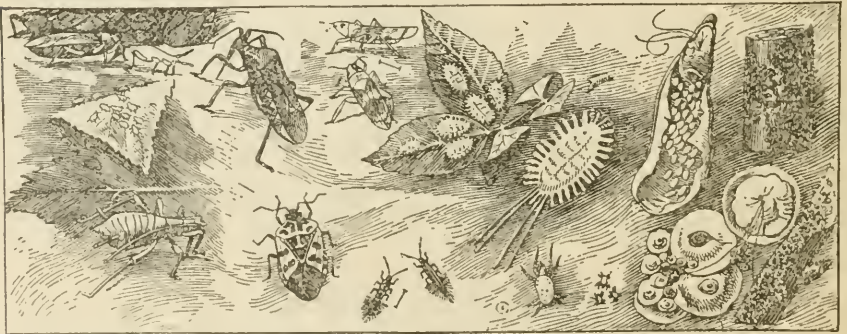


FIG. 2.—Illustrating the different classes of sucking insects. Natural size and enlarged. (Author's illustration.)

into the soft, succulent tissues beneath and used to extract the plant juices, with a resulting injury not so noticeable as in the first group, but not less serious. (See fig. 2.)

For this class of insects the application of poisons, which penetrate little, if at all, into the plant cells, is of trifling value, and it is necessary to use substances which will act externally on the bodies of these insects as a caustic, or will smother or stifle them by closing their breathing pores, or will fill the air about them with poisonous fumes. Of value also as repellents are various deterrent or obnoxious substances.

Where it is not desirable to use poisons for biting insects some of the means just enumerated may often be employed.

GROUPS SUBJECT TO SPECIAL TREATMENT.

The two general groups outlined above comprise the species which live and feed upon the exterior of plants for some portion or all of their lives, and include the great majority of the injurious species. Certain insects, however, owing to peculiarities of habit, inaccessibility, or other causes, require special methods of treatment. Of these, two groups properly come within the scope of this bulletin: (1) Those working beneath the soil, or subterranean insects, such as the white grubs, root maggots, root aphides, etc.; and (2) insects affecting stored products, as various grain and flour pests.

Three other groups, which include species requiring very diverse methods of treatment, and which are not considered in this bulletin, are (1) such internal feeders as wood, bark, and stem borers, leaf miners, and gall insects, and species living within fruits; (2) household pests; and (3) animal parasites.

The classification of insects outlined above, based on mode of nourishment, and indicating groups amenable to similar remedial treatment, simply stated, is as follows:

I. External feeders:

(a) Biting insects.

(b) Sucking insects.

II. Internal feeders.

III. Subterranean insects.

IV. Insects affecting stored products.

V. Household pests.

VI. Animal parasites.

INSECTICIDES FOR EXTERNAL BITING INSECTS (FOOD POISONS).

THE ARSENICALS.

The arsenical compounds have supplanted practically all other substances for insects falling under this heading. Of these, Paris green is the best known and most generally employed, and probably from 2,000 to 3,000 tons of it are used for horticultural purposes every year. Arsenate of lead is a new arsenical coming into very general use, and arsenite of copper, a near ally of Paris green, is also increasingly employed. Arsenite of lime is usually a home preparation, and London purple, the least uniform in composition of all the mixtures, is rather going out of use. The powdered white arsenic or

arsenious oxide can not be employed on account of its scalding action on the foliage, and in the case of any of the arsenicals the percentage of soluble arsenic (arsenious oxide) should be at the very minimum, certainly not in excess of 3 or 4 per cent. With more than 4 per cent soluble arsenic there is great danger of scalding the foliage, the danger increasing with the percentage of soluble arsenic.^a

Paris green.—Paris green is a definite chemical compound of white arsenic, copper oxide, and acetic acid, and is known as the aceto-arsenite of copper. Properly compounded and washed, it should be substantially uniform in composition and nearly free from uncombined soluble white arsenic. It is a rather coarse powder, or, more properly speaking, crystal, and settles rapidly in water, which is its greatest fault. To give better suspension in water, it should be reduced to such fineness by grinding that it will pass through a 100-mesh sieve. Its high cost (varying from 20 to 40 cents a pound, following the market price of copper and arsenic) is further increased by its being crystallized with acetic acid, making it a more brilliant pigment, but giving it a coarse grain and rendering it a poorer insecticide. The standards of purity demanded by various States have led most manufacturers to produce a very fair article, but if there is any doubt of purity a sample should be submitted to the State Experiment Station or to the United States Department of Agriculture for analysis.

Copper arsenite.—Copper arsenite, often called Scheele's green, is the simple arsenite of copper, differing from Paris green in lacking acetic acid. It is a much finer powder than Paris green and therefore is more easily kept in suspension, and it costs considerably less per pound. It is dull in color, lacking the brilliancy of Paris green. When properly prepared and washed by the manufacturers, it is no more harmful to the foliage than Paris green when the latter is brought to an equal fineness, and should supplant the latter as an insecticide. It is used in the same way and at about the same strength as Paris green.

^a *Hellebore.*—The powdered roots of the white hellebore (*Veratrum viride*) are often recommended and used as an insecticide, particularly as a substitute for the arsenites. This substance is useful when a few plants only are to be sprayed, as in yards and small gardens, but is too expensive for large operations. It kills insects in the same way as the arsenicals, as an internal poison, and is less dangerous to man and the higher animals; but if a sufficient amount be taken it will cause death. It is particularly effective against the larvæ of sawflies, such as the cherry slug, rose slug, currant worms, and strawberry worms.

It may be applied as a dry powder, preferably diluted with from 5 to 10 parts of flour, and dusted on the plants through a muslin bag or with powder bellows. The application should be made in the morning, when the plants are moist with dew. Used as a wet application, it should be mixed with water in the proportion of 1 ounce to the gallon of water and applied as a spray.

Arsenite of lime.—This is normally a home-made preparation, and there is no reason for its not being employed wherever one is willing to take the trouble to compound it carefully. Its preparation, described below, following substantially the Kedzie formula, is simple enough:

White arsenic.....	pounds..	1
Crystal sal soda ^a	do....	4
Water	gallons..	1

Place the above ingredients in an iron vessel, which is to be kept exclusively for this purpose, and boil for twenty minutes or until dissolved. To 40 or 50 gallons of water a pint of this stock solution and 3 to 4 pounds of freshly slaked lime are added. This excess of lime not only takes up any free arsenic, but by its distribution on the foliage enables one to determine how well the spraying has been done. This formula has been thoroughly tested and used now for many years, and is fully as efficient as any other arsenical and far cheaper. Chemically it is arsenite of lime. The soda is used to hasten the process and to insure the combination of all the arsenic with the lime. The greatest care should be exercised in preparing the stock mixture, and afterwards it should be plainly labeled to prevent its being mistaken for some other substance. The only objection to its use is the necessity of handling the poisons in its home preparation.

London purple.—London purple is a waste product in the manufacture of aniline dyes and contains a number of substances, the chief of which are white arsenic and lime. It is not so effective as the copper arsenites, and contains a much larger percentage of soluble arsenic, and is very apt to scald foliage unless very carefully mixed with fresh stone lime. It comes as a very fine powder, and is easily kept in suspension. It costs about 10 cents a pound. If employed, the lime should always be added.

Arsenate of lead.—Arsenate of lead may be prepared at home by combining approximately 3 parts of the crystallized arsenate of soda with 7 parts of crystallized acetate of lead (sugar of lead) in water. This gives a slight excess of acetate of lead. Each of the ingredients should be dissolved separately in water in wooden vessels, and the two solutions poured together into the spray tank filled with water. The white, flocculent precipitate of arsenate of lead which immediately results is extremely fine and remains in suspension much longer than any other arsenical. Furthermore, prepared in this way and diluted at once, there is secured a mixture that is chemically superior to the combined product sold in paste form and that remains in

^a Two pounds only of the *anhydrous* sal soda are necessary.

suspension better. Arsenate of soda costs wholesale about 10 cents a pound, and first-class acetate of lead about 10 cents a pound.

Arsenate of lead may be used at any strength from 3 to 15 pounds to 100 gallons of water without injury to the foliage, for the reason that it contains little, if any, soluble arsenic. It is ordinarily used at the rate of 4 to 6 pounds to the 100 gallons of water or Bordeaux mixture. In later years it has come into general use, especially for spraying plants sensitive to arsenical poisoning, such as peach, and also in cases where it is necessary to make heavy applications. Its safety as regards the burning of foliage and its adhesive quality offset its greater cost, and it is now much used in the codling moth work and general arsenical spraying.

In the home preparation of this arsenical, the number of pounds of the poison per 100 gallons of water as given in directions for use should be understood to mean the combined weights of the two ingredients. In point of fact, the resulting lead arsenate is only about half the actual weight of the two ingredients, which explains in part the apparently excessive amounts used as compared with other arsenicals.

A good many brands of arsenate of lead can be purchased on the market, usually in the form of heavy pastes. As already indicated, they have not the same power of remaining in suspension as the freshly made product, but are otherwise, if properly made, quite satisfactory. The water content, which is variable, should be specifically indicated and guaranteed, to make it possible to use the poison at the strength desired.

Arsenite of lead is a compound very similar to the arsenate of lead, but it contains a less percentage of arsenic. It is prepared from sodium arsenite.

General considerations.—In point of solubility and corresponding danger of scalding the foliage, these arsenicals fall in the following order, the least soluble first: Arsenate of lead, arsenite of lime, Paris green, copper arsenite, and London purple. In point of cost the arsenite of lime is much cheaper than the other arsenicals, and the arsenate of lead, at the rate at which it is necessary to use it, much the most expensive. But after all the main cost is in the application, and it is therefore well worth while to secure a good arsenical and get the best results.

HOW TO APPLY ARSENICALS.

There are three principal methods of applying arsenicals. The wet method, which consists in using these poisons in water in the form of spray, is the standard means, secures uniform results at least expense, and is the only practical method of protecting fruit and shade trees.

The dry application of these poisons in the form of a powder, which is dusted over plants, is more popular as a means against the cotton worm in the South, where the rapidity of treatment possible by this method, and its cheapness, give it a value against this insect, in the practical treatment of which prompt and economical action are the essentials. This method is also feasible for any low-growing crop, such as potatoes, young cabbages, or other plants not to be immediately employed as food. The third method consists in the use of the arsenicals in the form of poisoned baits, and is particularly available for such insects as cutworms, wireworms, and grasshoppers in local invasions.

The wet method.—Either Paris green, arsenite of copper, arsenite of lime, or London purple may be used at the rate of 1 pound of the poison to 100 to 250 gallons of water, or 1 ounce to 6 to 15 gallons. The stronger mixtures are for such vigorous foliage as that of the potato, and the greater dilutions for the more tender foliage of the peach or plum. An average of 1 pound to 150 gallons of water is a good strength for general purposes. The poison should first be made into a thin paste in a small quantity of water and quicklime added in amount equal to the poison used, to take up the free arsenic and remove or lessen the danger of scalding. An excess of lime will do no injury. The poisons thus mixed should be strained into the spray tank or reservoir, care being taken that all the poison is pulverized and washed through the meshes of the strainer. The use of the lime is especially desirable in the case of the peach and plum, the foliage of which, particularly the former, is very tender and easily scalded. To the stronger foliage of the apple and most shade trees Paris green may be applied without danger at the strength of 1 pound to 150 gallons of water; with London purple it is always better to use the lime. The method of preparation of arsenate of lead has already been indicated. Lime is not needed with this arsenical.

If it be desirable to apply a fungicide at the same time, as on the apple for the codling moth and the apple scab fungus, the Bordeaux mixture^a may be used instead of water, adding the arsenical to it at the same rate per gallon as when water is used. The lime in this fungicide neutralizes any excess of free arsenic and makes it an excellent medium for the arsenical, as it removes liability of scalding the foliage and permits an application of the arsenical, if necessary, eight or ten times as strong as it could be employed with water alone.

The arsenicals can not be safely used with most other fungicides, such as the sulphate of copper, eau celeste, or iron chloride solution, the scalding effects of these being greatly intensified in the mixture.

The dry method.—The following description applies to the pole-

^a See F. B. 243, Fungicides and Their Use in Preventing Diseases of Fruits.

and-bag duster commonly used against the cotton worm: A pole 5 to 8 feet long and about 2 inches in diameter is taken, and a three-fourths-inch hole bored through it within 6 inches of each end. Near each end is securely tacked a bag of "8-ounce osnaburg cloth," 1 foot wide and 18 inches to 2 feet long, so that the powdered poison may be introduced into the bags with a funnel through the holes at the ends of the pole. The bags are filled with undiluted Paris green, which is generally preferred to London purple on account of its quicker action, and the apparatus is carried on horse or mule back, through the cotton fields, dusting two or four rows at once. The shaking induced by the motion of the animal going at a brisk walk or at a trot is sufficient to dust the plants thoroughly, or the pole may be jarred by hand. The application is preferably made in early morning or late evening, when the dew is on, to cause the poison to adhere better to the foliage.

From 1 to 2 pounds are required to the acre, and from 10 to 20 acres are covered in a day. The occurrence of heavy rains may necessitate a second application, but frequently one will suffice. This simple apparatus, on account of its effectiveness and cheapness, is employed throughout the cotton belt to the general exclusion of more complicated and expensive machinery. The cost frequently does not exceed 25 cents per acre, and the results are so satisfactory that the leaf worm is no longer considered a serious factor in cotton culture.

With the patented air-blast machines for the dry distribution of poisons, arsenicals are diluted with 10 parts of flour, lime, or ground gypsum, and from 60 to 75 acres may be covered in a day by using relays of men and teams. Greater uniformity is secured with these machines in distribution of the poisons, but their cost (from \$30 to \$60) prevents their general use.

The planter should have a good supply of poison on hand and apparatus for its application prepared in advance, since when the worm puts in an appearance its progress is very rapid, and a delay of a single day may result in material damage to the crop.

If small garden patches are dusted with poison by this or similar means from bags or with hand bellows, it is advisable always to dilute the poison with 10 parts of flour, or preferably lime, and for application to vegetables which ultimately will be used for food, as the cabbage, 1 ounce of the poison should be mixed with 6 pounds of flour or 10 of lime and dusted merely enough to show evenly over the surface. Arsenicals should not be applied to lettuce or other vegetables the free leafage of which is eaten.

Poisoned bait.—It is not always advisable or effective to apply arsenicals directly to the plants, and this is particularly true in relation to the attacks of the grasshopper and of the various cutworms

and wireworms. In such cases the use of poisoned bait has proved very satisfactory.

For grasshoppers, take 1 part, by weight, of white arsenic, 1 of sugar, or molasses, and 6 of bran, to which add water to make a wet mash. Place a tablespoonful of this at the base of each tree or vine, or apply a line of baits just ahead of the advancing army of grasshoppers, placing a tablespoonful of the mash every 6 or 8 feet and following up with another line behind the first.

A cheap grasshopper bait used successfully in parts of the West is obtained by mixing fresh horse droppings with arsenicals. One pound of Paris green, or some other convenient arsenical, together with 2 pounds of salt, are thoroughly mixed with 60 pounds of fresh horse droppings. The resulting mixture is scattered among the young "hoppers" or around the edges of fields which it is thought may be invaded. A very convenient receptacle in which to make this preparation is a half barrel. A trowel or paddle can be used in scattering the mixture in the desired places.

Bran and Paris green, on the authority of Prof. J. B. Smith, thoroughly mixed and sprinkled dry on cabbage heads, proved a most successful remedy for cabbage worms, the latter preferring the poisoned bran to the cabbage, to their prompt undoing. The same dry mixture has been successfully employed against cutworms and is recommended by Smith for the army worm, running it in rows 10 feet apart across the infested field. One pound of poison to 10 of bran is a good proportion. The bran-arsenic bait may also be used for cutworms.

For sowbugs, or pill bugs, which frequently are injurious pests to tender flowering plants and vegetables grown under frames or in glass houses, poisoned slices of potato have proved to be the most effectual remedy. The freshly sliced potato may be poisoned by dipping in a strong arsenical solution, or by dusting thickly with a dry arsenical, and should then be distributed over the beds. Pansy beds have been notably protected in this way, and a Michigan vegetable grower reports that in two nights he destroyed upward of 24,000 of these bugs by this means in four houses used for lettuce growing.

Another remedy for cutworms and also for wireworms is poisoned green succulent vegetation, such as freshly cut clover, distributed in small bunches in the infested fields. Dip the bait in a very strong arsenical solution, and protect it from drying by covering. Renew the bait as often as it becomes dry, or every three to five days.

TIME TO SPRAY FOR BITING INSECTS.

Specific directions for spraying with arsenicals to control important insect pests are given in Farmers' Bulletins or in circulars of this Bureau relating to these different insects. One of the princi-

pal uses of arsenical poisons is for the control of the codling moth. Detailed information on the subject is given in Farmers' Bulletins Nos. 247 and 283. The plum curculio is discussed in Circular No. 73, and leaf-feeding grape insects in Farmers' Bulletin No. 284. Other publications relating to special insect problems are also available giving detailed directions for spraying.

For leaf-feeding insects in general, such as the Colorado potato beetle, blister beetles, elm leaf-beetle, maple worm, and other forest or shade-tree caterpillars, the application should be made at the earliest indication of injury, and repeated as often as necessary. Fruit trees should never be sprayed when in bloom, on account of the liability of poisoning honey bees or other insects useful as cross-fertilizers.

There is no basis for the idea occasionally advanced that the frequent use of Paris green or other arsenicals on potatoes and other crops is injurious to the foliage or health of the treated plants. This matter has been fully tested, and the injurious results can always be accounted for by improper mixtures or applications.

CARE IN THE USE OF ARSENICALS.

It must be remembered that these arsenicals are very poisonous and should be so labeled. If ordinary precautions are taken, there is no danger to man or team attending their application. The wetting of either, which can not always be avoided, is not at all dangerous, on account of the great dilution of the mixture, and no ill effects whatever have resulted from this source. With some individuals the arsenate of lead, when in strong mixture, affects the eyes, but this is unusual, and, with a little care in spraying, the mist need not strike the operator at all.

The poison disappears from the plants almost completely within twenty to twenty-five days, and even if the plants were consumed shortly after the application, an impossible quantity would have to be eaten to get a poisonous dose. To illustrate, in the case of the apple, if the entire fruit were eaten, core and all, it would take several barrels at a single sitting to make a poisonous dose (Riley), and with the cabbage, dusted as recommended above, 28 heads would have to be eaten at one meal to reach this result (Gillette). It is preferable, however, to use other insecticides in the case of vegetables soon to be eaten, and thus avoid all appearance of danger.

INSECTICIDES FOR EXTERNAL SUCKING INSECTS (CONTACT POISONS).

The simple remedies for this class of insects, such as soap, insect powder, sulphur, tobacco decoction, etc., are frequently of value, but need little special explanation. Some brief notes will be given, how-

ever, describing the methods of using some of these substances which are easily available and will often be of service, particularly where few plants are to be treated. The standard remedies for this group of insects, viz, crude petroleum, kerosene, and kerosene emulsions, resin washes, lime-sulphur wash, hydrocyanic acid gas, and vapor of bisulphid of carbon, will be treated farther on.

SOAPS AS INSECTICIDES.

Any good soap is effective in destroying soft-bodied insects, such as aphides and young or soft-bodied larvæ. As winter washes in very strong solution, they furnish one of the safest and most effective means against scale insects. The soaps made of fish oil and sold under the name of whale-oil soaps are often especially valuable, but they are variable in composition and merits. A soap made with caustic potash rather than with caustic soda which is commonly used, and not containing more than 30 per cent of water, should be demanded, the potash soap yielding a liquid in dilution more readily sprayed and more effective against insects. The soda soap washes are apt to be gelatinous when cold, and difficult or impossible to spray except when kept at a very high temperature.

For aphides and delicate larvæ, such as the pear slug, a strength obtained by dissolving half a pound of soap in a gallon of water is sufficient. For the pea aphid as little as 1 pound of potash fish-oil soap to 6 gallons has been effective. Soft soap will answer as well as hard, but at least double quantity should be taken.

As a winter wash for the San Jose and allied scale insects, whale-oil or fish-oil soap is dissolved in water by boiling at the rate of 2 pounds of soap to the gallon of water. If applied hot and on a comparatively warm day in winter, it can be easily put on trees with an ordinary spray pump. On a very cold day, or with a cold solution, the mixture will clog the pump and difficulty will be experienced in getting it on the trees. Trees should be thoroughly coated with this soap wash. Pear and apple trees may be sprayed at any time during the winter. Peach and plum trees are best sprayed in the spring, shortly before the buds swell. If sprayed in midwinter or earlier, the soap solution seems to prevent the development of the fruit buds, and a loss of fruit for one year is apt to be experienced, the trees leafing out and growing, however, perhaps more vigorously on this account. The soap treatment is perfectly safe for all kinds of trees, and is very effective against the scale. With large trees, or badly infested trees, as a preliminary to treatment, it is desirable with this as well as other applications to prune them back very rigorously. This results in an economy of spray and makes much more thorough and effective work possible. The soap can be secured in large quantities at from $3\frac{1}{2}$

cents to 4 cents a pound, making the mixture cost, as applied to the trees, from 7 cents to 8 cents a gallon.

PYRETHRUM, OR INSECT POWDER.

This insecticide is sold under the names of Buhach, Dalmatian, and Persian insect powder, or simply insect powder, and is the ground-up flowers of the Pyrethrum plant. It acts on insects externally through their breathing pores, and is fatal to many forms both of biting and sucking insects. It is not poisonous to man or the higher animals, and hence may be used where poisons would be objectionable. Its chief value is against household pests, such as roaches, flies, and ants, and in greenhouses, conservatories, and small gardens, where the use of arsenical poisons would be inadvisable.

It is used as a dry powder, pure or mixed with flour, in which form it may be puffed about rooms or over plants. On the latter it is preferably applied in the evening, so as to be retained by the dew. To keep out mosquitoes, and also to kill them, burning the powder in a tent or room will give satisfactory results.

It may also be used as a spray at the rate of 1 ounce to 2 gallons of water, but in this case should be mixed some twenty-four hours before being applied. For immediate use, a decoction may be prepared by boiling in water from five to ten minutes.

TOBACCO DECOCTION.

A tobacco decoction sufficiently strong for aphides and other very delicate insects may be prepared from tobacco stems and other refuse tobacco by boiling at the rate of 1 pound for each 1 or 2 gallons of water, sufficient water being added to make up for that lost in boiling.

SULPHUR.

Flowers of sulphur is one of the best remedies for plant mites, such as the red spider, the six-spotted orange mite, and the rust mite of citrus fruits. It may be applied in several forms, the simplest of which is its use as a dry powder dusted over the trees with powder bellows or any broadcasting device, preferably in the early morning when the foliage is damp with dew, or immediately after a rain. For the rust mite in very moist climates, such as that of Florida, to keep the fruit bright it is sufficient merely to sprinkle the sulphur about under the trees. The flowers of sulphur may be easily applied also with any other insecticide, such as kerosene emulsion, resin wash, or a soap wash, mixing it up first into a paste and then adding it to the spray tank at a rate of from 1 to 2 pounds to 50 gallons.

Somewhat more uniform results can be obtained perhaps by getting the sulphur into solution, either dissolving it with lye or by boiling it with lime.

In making the lye-sulphur wash, first mix 20 pounds of flowers of sulphur into a paste with cold water, then add 10 pounds of pulverized caustic soda (98 per cent). The dissolving lye will boil and liquefy the sulphur. Water must be added from time to time to prevent burning, until a concentrated solution of 20 gallons is obtained. Two gallons of this is sufficient for 50 gallons of spray, giving a strength of 2 pounds of sulphur and 1 of lye to 50 gallons of water. An even stronger application can be made without danger to the foliage. This mixture can also be used in combination with other insecticides.

The chemical combination of sulphur and lime known as sulphid of lime is perhaps a better liquid sulphur solution than the last as a remedy for mites. It may be very cheaply prepared by boiling together for an hour or more, in a small quantity of water, equal parts of flowers of sulphur and stone lime. A convenient quantity is prepared by taking 5 pounds of sulphur and 5 of lime and boiling in 3 or 4 gallons of water until the ingredients combine, forming a brownish liquid. This may be diluted to make 100 gallons of spray.

Almost any of the insecticides with which the sulphur may be applied will kill the leaf or rust mites, but the advantage of the sulphur arises from the fact that it forms an adhering coating on the leaves and kills the young mites coming from the eggs, which are very resistant to the action of insecticides.

A strongly intrenched popular fallacy, often exposed but constantly being revived, is that sulphur is a valuable remedy against insects when put into holes bored into the trunks of trees, the idea being that the sulphur, when plugged in, is carried up by the movement of the sap into the branches and distributed in the foliage, rendering the latter distasteful to insects. In point of fact, the sulphur remains exactly where it is placed, and is of no possible advantage from an insecticide standpoint or any other, and furthermore the treatment is mischievous in that it injures to that extent the soundness of the trunk.

PETROLEUM OILS.

The emulsions of kerosene, or coal oil, with soap or milk have long been the standard insecticides for external sucking insects, and especially the aphides and scale insects, and these emulsions still are the safest and most reliable means of getting these oils upon plants. The use of kerosene in the pure state as an insecticide was early experimented with by Comstock and Hubbard, and the feasibility of such applications was demonstrated, but the greater safety in the use of the emulsions resulted in a discontinuance of the use of the pure oils. Especially during the last twelve years, however, the use of these

oils in the pure state has come into very general vogue, more particularly as winter washes for the San Jose scale and allied scale insects, the value of the crude oil being especially demonstrated by Prof. J. B. Smith. The petroleum oils may also be mechanically combined with water by means of especially adapted spray pumps.

In addition to its direct application to plants, kerosene is often used as a means of destroying insects by jarring the latter from plants into pans of water on which a little of the oil is floating, or by jarring them upon cloths or screens saturated with kerosene, preferably the crude oil. The same principle is illustrated in some of the hopper-dozers, or machines for collecting grasshoppers and leaf-hoppers.

As a remedy for mosquitoes, kerosene has proved very effective. It is employed to destroy the larvæ of the mosquitoes in their favorite breeding places in small pools, still ponds, or stagnant water; and where such bodies of water are not sources of drinking supply or of value for their fish, especially in the case of temporary pools from rains, which frequently breed very disagreeable local swarms, the use of oil is strongly recommended. The kerosene is applied at the rate of 1 ounce to 15 square feet of water surface. It forms a uniform film over the surface and destroys all forms of aquatic insect life, including the larvæ of the mosquito, and also the adult females coming to the water to deposit their eggs. The application retains its efficiency for several weeks, even with the occurrence of heavy rains. A light grade of fuel oil is preferred for this purpose.

The methods of using kerosene in the pure state and as emulsions with soap and milk follow.

Pure-kerosene treatment.—This consists in spraying the trees with ordinary illuminating oil (coal oil or kerosene). The application is made at any time during the winter, preferably in the latter part, and by means of a spray pump making a fine mist spray. The application should be made with the greatest care, merely enough spray being put on the plant to moisten the trunk and branches without causing the oil to flow down the trunk and collect about the base. With the use of this substance it must be constantly borne in mind that careless or excessive application of the oil will be very apt to kill the treated plant. The application should be made on a bright, dry day, so that the oil will evaporate as quickly as possible. On a moist, cloudy day the evaporation is slow, and injury to the plant is more apt to result. If the kerosene treatment be adopted, therefore, it must be with a full appreciation of the fact that the death of the tree may follow. This oil has been used, however, a great many times and very extensively without consequent injury of any kind. On the other hand, its careless use has frequently killed valuable trees. Its advantages are its effectiveness, its availability, and its cheapness, kerosene spreading

very rapidly and much less of it being required to wet the tree than of a soap and water spray. Pure kerosene is more apt to be injurious to peach and plum than to pear and apple trees, and the treatment of the former, as with the soap wash, should be deferred until spring, just before the buds swell. With young trees especially it is well to mound up about the trunk a few inches of earth to catch the overflow of oil, removing the oil-soaked earth immediately after treatment.

The crude-petroleum treatment.—Crude petroleum is used in exactly the same way as is the common illuminating oil referred to above. Its advantages over kerosene are that, as it contains a very large percentage of the heavy oils, it does not penetrate the bark so readily, and, on the other hand, only the light oils evaporate, leaving a coating of the heavy oils on the bark, which remains in evidence for months and prevents any young scale, which may come from the chance individuals not reached by the spray, from getting a foothold. Crude petroleum comes in a great many different forms, depending upon the locality, the grade successfully experimented with in the work of this Bureau showing 43° Baumé. Crude oil showing a lower Baumé than 43° is unsafe, and more than 45° is unnecessarily high. The lower specific gravity indicated (43°) is substantially that of the refined product, the removal of the lighter oils in refining practically offsetting the removal of the paraffin and vaseline. The same cautions and warnings apply to the crude as to the refined oil.

The oil-water treatment.—Various pump manufacturers have now placed on the market spraying machines which mechanically mix kerosene or crude petroleum with water in the act of spraying. The attempt is made to regulate the proportion of kerosene so that any desired percentage of oil can be thrown out with the water and be broken up by the nozzle into a sort of emulsion. Some of these machines, when everything is in good working order, give fairly satisfactory results, but absolute reliability is far from assured. The best outlook for good apparatus of this sort seems to be in carrying the oil and water in separate lines of hose to the nozzle, uniting them in the latter, and in maintaining an absolute equality of pressure on both the oil and the water tanks by employing compressed air as the motive force, kept up by an air pump, the air chamber communicating with both of the liquid receptacles. One or more manufacturers are now working on apparatus of this general description. A 10-per-cent-strength kerosene can be used for a summer spray on trees where the San Jose scale is multiplying rapidly and where it is not desirable to let it go unchecked until the time for the winter treatment. The winter treatment with the water-kerosene sprays may be made at a strength of 20 per cent of the oil. Applications of the oil-water spray should be attended with the same precautions as with the pure

oil, and there is even somewhat greater risk, owing to the natural tendency one has to apply the dilute mixture much more freely than the pure oil. The application should be merely enough to wet the bark and the mixture should not, to any extent at least, run down the trunk, as it is just as dangerous to the tree as the pure oil.

In the use of the oil sprays noted above, one who has not had experience with them is advised to make some careful preliminary tests to fully master the process, preferably waiting two or three weeks to determine the results before entering on the general treatment of the orchard. It is well, also, with the oil-water mixtures to test the pump from time to time, spraying into a glass jar or bottle to determine by actual measurement whether the correct percentages of oil and water are being maintained.

Kerosene emulsion (soap formula).—The kerosene-soap emulsion, following chiefly the Riley-Hubbard formula, has been one of the standard means against scale insects for twenty years. The distillate emulsion generally employed in California for spraying citrus and other trees is substantially the same thing, except that it is made with the California distillate or petroleum oil. Crude petroleum of any kind, as well as the refined product, may also be used in making this emulsion. The use of the soap emulsions against the San Jose scale in the East has not been very general, on account of the greater facility with which the pure oil or oil-water mixtures can be applied. The difficulty of obtaining uniform results with the latter has led to a return to the use of emulsions to some extent, and there can be no doubt about their superior merit when it is desired to dilute the pure oils. Emulsions may be applied at any strength with absolute confidence that there will be no variation. Where the emulsion can be prepared wholesale by steam power, its employment is attended with no difficulties. In California it is prepared by oil companies and sold at very slightly more than the cost of the oil and soap ingredients. It is made after the following formula:

Petroleum	gallons..	2
Whale-oil soap (or 1 quart soft soap)	pound..	$\frac{1}{2}$
Water (soft)	gallon..	1

The soap, first finely divided, is dissolved in the water by boiling and immediately added boiling hot, away from the fire, to the oil. The whole mixture is then agitated violently while hot by being pumped back upon itself with a force pump and direct-discharge nozzle throwing a strong stream, preferably one-eighth inch in diameter. After from three to five minutes' pumping the emulsion should be perfect, and the mixture will have increased from one-third to one-half in bulk and assume the consistency of cream. Well made, the emulsion will keep indefinitely and should be diluted only as wanted for use.

In limestone regions, or where the water is very hard, some of the soap will combine with the lime or magnesia in the water, and more or less of the oil will be freed, especially when the emulsion is diluted. Before use, such water should be broken with lye, or rain water should be employed.

Kerosene emulsion (milk formula).—This formula is as follows:

Kerosene -----	gallons--	2
Milk (sour) -----	gallon--	1

Heating is unnecessary in making the milk emulsion, which otherwise is churned as in the former case. The change from a watery liquid to a thick buttery consistency, much thicker than with the soap, takes place very suddenly after three to five minutes' agitation. With sweet milk difficulty will frequently be experienced, and if the emulsion does not result in five minutes, the addition of a little vinegar will induce prompt action. It is better to prepare the milk emulsion from time to time for immediate use, unless it can be stored in quantity in air-tight jars; otherwise it will ferment and spoil after a week or two.

The distillate emulsion.—This wash was originated by Mr. F. Kahles, of Santa Barbara, Cal. It has been recommended by the California State board of horticulture and has found very general use in the citrus sections of the State. It is substantially an emulsion of crude petroleum, made in the same way as the kerosene emulsion described above, except that a greater amount of soap and only half as much oil proportionately is used. The lessened quantity of oil enables it to be made comparatively cheaply, and in spite of this reduction in the oil, the wash is, if anything, stronger than kerosene emulsion, judging from the experience of the writer with both these washes in southern California.

It is termed distillate spray, because the oil used is a crude distillate of the heavy California petroleum. The product used for preparing the emulsion should have a gravity of about 28° Baumé, and is the crude oil minus the lighter oil, or what distills over at a temperature between 250° and 350° C. In general characteristics it is very similar to lubricating oil. The emulsion, or, as it is generally known, "cream," is prepared as follows: Five gallons of 28° gravity distillate; 5 gallons of water, boiling; 1 to 1½ pounds of whale-oil soap. The soap is dissolved in hot water, the distillate added, and the whole thoroughly emulsified by means of a power pump until a rather heavy yellowish, creamy emulsion is produced. The product is very similar to, but rather darker in color than the ordinary kerosene emulsion. For use on citrus trees it is diluted with from 12 to 15 parts of water, the stronger wash for the lemon and the weaker for the orange. The "distillate cream" is commonly prepared and sold by oil companies or individuals at from 10 to 12 cents a gallon,

making the diluted mixture cost in the neighborhood of a cent a gallon.

The distillate spray has the same range of application as kerosene emulsion. In California it has been used extensively for the spraying of citrus trees, and when so used has been often charged with injury to trees and especially resulting in spotting of fruit. If this spray be applied to citrus plants in spring and summer, there is danger of the spotting and dropping of the young fruit and leaves. Where several applications may be necessary each year, gas fumigation is undoubtedly preferable. Nevertheless it has been fully demonstrated that any applications made to citrus trees during the comparatively dormant season in October and November, with a second treatment if necessary in January and February, the latter just before the flower spurs start, results in no injury.

How to use the emulsions.—During the growing period of summer, for most aphides and other soft-bodied insects, dilute the emulsion with 15 parts of water; for the red spider and other plant-mites, the same, with the addition of 1 ounce of flowers of sulphur to the gallon; for scale insects, the larger plant-bugs, larvæ, and beetles, dilute with from 7 to 10 parts of water. Apply with spray pump. The greatest dilution noted gives 4 per cent of oil and the lesser dilutions approximately 6 and 8 per cent.

For winter applications to the trunks and limbs of trees in the dormant and leafless condition to destroy scale insects, stronger mixtures may be used, even to the pure emulsion, which can not be sprayed successfully but may be applied with brush or sponge. Diluted with one or more parts of water it may be applied in spray without difficulty. The use of the pure emulsion is heroic treatment and only advisable in cases of excessive infestation.

The winter strengths recommended are the emulsion diluted with either 3, 4, or 5 parts of water, giving approximately 17, 13, and 11 per cent of oil. These dilutions are equivalent in strength to oil-water sprays containing 25, 20, and 15 per cent of oil, because relatively more of the emulsion is held by the bark. The two stronger mixtures may be used on the apple and pear and the weaker one on peach and plum.

The winter treatment may be followed in June by a use of the summer wash to destroy any young which may come from female scales escaping the stronger mixture.

Cautions regarding use of oil washes.—In the use of kerosene washes, and, in fact, of all oily washes on plants, the application should be just sufficient to wet the plant without allowing the liquid to run down the trunk and collect about the root. Usually, in the case of young trees at least, there is a cavity formed by the swaying of the tree in

the wind, and accumulation of the insecticide at this point, unless precautions be taken, may result in the death or injury of the plant. Under these conditions it may be advisable to mound up the trees before spraying and firmly pack the earth about the bases. Care should be taken in refilling the tank that no free oil is allowed to accumulate gradually in the residue left at the bottom when spraying with emulsions or oil-water mixtures.

Miscible oils.—It will be noted that the difficulty to be overcome in the use of oils is to effect their dilution to render them harmless to the plant. This dilution is effected with great accuracy by the kerosene-soap emulsions, and less accurately by the mechanical emulsions of oil and water. There have appeared during the last few years various so-called miscible oils, which readily and permanently mix with water, and can be applied with the same readiness and accuracy of strength as the emulsion of kerosene and soap. These oils have for their principal ingredient some form of petroleum rendered soluble by the addition of a percentage of vegetable oils and cut or saponified with an alkali, and they are, in fact, a sort of liquid petroleum soap. They are sold under various trade names. They have the disadvantage of costing a good deal more than the standard emulsions or the lime-sulphur wash (see p. 24), but have the great advantage of being always ready for immediate use without troublesome preparation. They can not be diluted for winter applications against scale insects with more than 10 or 15 parts of water to give good results, and there is some danger of injury to the trees if they are carelessly or excessively applied. They have, however, a very useful place, and especially as furnishing a good insecticide where only a few trees are to be treated and the owner would probably not go to the trouble of preparing an emulsion or the lime-sulphur wash. They have been so far principally used against the San Jose scale as dormant tree washes.

THE RESIN WASH.

The resin wash has proved of greatest value in California, particularly against the red scale (*Chrysomphalus aurantii* Mask.) and the black scale (*Saissetia oleæ* Bern.) on citrus plants, and the last named and the San Jose scale (*Aspidiotus perniciosus* Comst.) on deciduous plants, and will be of use in all similar climates where the occurrence of comparatively rainless seasons insures the continuance of the wash on the trees for a considerable period, and where, owing to the warmth, the multiplication of the scale insects continues almost without interruption throughout the year. Where rains are liable to occur at short intervals, and in the Northern States, the quicker-acting and stronger kerosene washes and heavy soap applications are

preferable. The resin wash acts by contact, having a certain caustic effect, but principally by forming an impervious, smothering coating over the scale insects. The application may be more liberal than with the kerosene washes, the object being to wet the bark thoroughly.

The wash may be made as follows:

Resin -----	pounds--	20
Crude caustic soda (78 per cent)-----	do-----	5
Fish oil -----	pints--	2½
Water to make-----	gallons--	100

Ordinary commercial resin is used, and the caustic soda is that put up for soap establishments, in large 200-pound drums. Smaller quantities may be obtained at soap factories, or the granulated caustic soda (98 per cent) may be used—3½ pounds of the latter being the equivalent of 5 pounds of the crude. Place these substances, with the oil, in a kettle with water to cover them to a depth of 3 or 4 inches. Boil about two hours, making occasional additions of water, or until the compound resembles very strong black coffee. Dilute to one-third the final bulk with hot water, or with cold water added slowly over the fire, making a stock mixture, to be diluted to the full amount as used. When sprayed the mixture should be perfectly fluid, without sediment, and should any appear in the stock mixture reheating should be resorted to; in fact the wash is preferably applied hot.

As a winter wash for scale insects, and particularly for the more resistant San Jose scale (*Aspidiotus perniciosus*), stronger washes are necessary. In southern California, for this insect, a dilution one-third less, or water to make 66⅔ gallons instead of 100 (see formula), has given good results. In Maryland, with this insect, it has proved necessary to use the wash at six times the summer strength to destroy all of the well-protected hibernating scales; and with other scale insects much stronger mixtures than those used in California have proved ineffectual in the East. For regions, therefore, with moderately severe winters the use of the resin wash to destroy hibernating scale insects seems inadvisable.

THE LIME-SULPHUR WASH.

In California, where the San Jose scale first appeared, the standard remedy for it is the lime-sulphur-salt wash, a mixture formerly used as a sheep dip in Australia and employed with little change against the San Jose scale. This wash was naturally first thought of on the discovery of the San Jose scale in eastern orchards. The earlier tests, however, conducted by this office in 1894, gave unfavorable results, and the experimentation which followed resulted in the demonstration of several distinct and valuable methods of control noted below.

Later studies of the action of this wash in California led the writer in 1900 to give it a further careful trial in the East, with most successful results, demonstrating that, with favoring conditions, i. e., absence of dashing rains for a few days after the application, it would give just as good results in the Eastern States as on the Pacific coast. A year later (1901-2) very elaborate tests conducted by Doctor Forbes in Illinois showed that fairly hard rains will not always invalidate spraying with this mixture. A vast amount of experience of the most practical kind since gained, contributed to by all the eastern experiment stations and by the big commercial fruit growers of the Middle and Eastern States, has fully demonstrated the practical merit of this wash and its superiority to others in point of safety to trees and in cheapness. Its disadvantages are the difficulty of preparation and the heavy wear which it entails on apparatus—objections, however, which do not offset its notable advantages, particularly for commercial orchard work or where the number of trees to be treated is sufficient to warrant the trouble of its preparation. It is, in fact, the standard spray now used in commercial orchards for the San Jose scale.

Composition and preparation.—In the matter of composition of the wash, scarcely any two experimenters agree. Salt was a part of the original composition of the sheep dip and has long been retained, with the idea that it added, perhaps, to the caustic qualities, and particularly to the adhesiveness of the wash. For the latter purpose a very small amount only, 1 or 2 pounds to the bushel of lime, need be added, following the custom in the preparation of whitewash mixtures. In practical experience, however, the salt seems to have been of very little benefit and is therefore omitted in the formula now given. The proportion of lime and sulphur is a matter of some indifference. The mixture obtained is sulphide of lime, and if an excess of lime is used it simply remains undissolved in the mixture and adds to the whitewashing character of the application. Too much lime is distinctly objectionable, however, because of the greater difficulty of spraying and harder wear on the pump and nozzles. The formula here given is substantially the one which has been hitherto recommended by this Bureau, reduced to the 45 or 50 gallon basis, or the capacity of the ordinary kerosene barrel commonly used in its preparation by the steam method.

Unslaked lime.....	pounds..	20
Flowers of sulphur.....	do....	15
Water to make.....	gallons..	45 to 50

The flowers of sulphur, although requiring somewhat longer cooking, seems to make a better wash than ground sulphur, but the latter may be employed. Stone lime of good quality should be secured and

slaked in a small quantity of water, say one-third the full dilution. The sulphur, previously mixed up into a stiff paste, should be added at once to the slaking lime. The whole mixture should be boiled for at least one hour, either in an iron kettle over a fire out of doors or in barrels by steam. Prolonged boiling increases the percentage of the higher sulphides, but the practical end is obtained by boiling for the time indicated. In the process of making, the color changes from yellow to the clear brown of sulphide of lime, except for the excess of lime floating in it. After an hour's boiling the full quantity of cold water can be added, and the mixture should then be promptly applied in order to get its full strength before the higher sulphides are lost by cooling and crystallizing out. In transferring to the spray tank it should be passed through an iron screen or strainer, and the tank itself should be provided with an effective agitator.

Directions for use.—The wash is a winter application and can not be applied to trees in leaf. It may be applied at any time after the falling of foliage in early winter and prior to the swelling of the buds in spring. The later the application can be made the better the results, and the best period is just before the buds swell in March or April. It will probably be necessary also to make this application every year, or at least as often as the San Jose scale develops in any numbers. The wash kills the San Jose scale not only by direct caustic action, but also by leaving a limy coating on the trees, which remains in evidence until midsummer or later and kills or prevents the settling of young scale insects which may come from parents escaping the winter action.

The wear on pumps and nozzles can be kept to a minimum by carefully washing the apparatus promptly after use. The Vermorel nozzle is the best one for the wash, and additional caps may be secured to replace worn ones. The use of an air or other gas pressure pump instead of the ordinary liquid pump will save the wear of the lime on the pump. In spraying with this wash clothing is ruined, and only the oldest garments should be worn. Care should be taken also to protect the eyes to avoid unnecessary inflammation.

Range of usefulness.—This wash is distinctively the remedy for the San Jose scale and is particularly effective in applications to the smooth-barked fruit trees—such as peach, pear, and plum. In the case of the apple the terminal twigs are often covered with a fuzzy growth, more pronounced in some varieties than others, which prevents the wash from properly coating the bark. The young from scale insects which escape destruction at such points, for the reason indicated or from imperfect spraying, are driven out onto the new growth, or, in the case of fruit spurs, onto the fruit, so that a tree on which the scale has been pretty thoroughly exterminated may never-

theless present badly spotted fruit.^a In such cases the additional use of some one of the oil sprays may be necessary.

This wash is of equal value against closely allied scale pests, such as Forbes's scale and the West Indian peach scale, and late sprayings are quite effective against the scurfy scale and the oyster-shell scale.

The spring application, just before the buds swell, has been demonstrated by Prof. J. M. Aldrich to kill most of the eggs of the apple aphid, and Mr. Fred Johnson, of this Bureau, has found that it is equally effective in destroying the eggs of the pear-tree *Psylla*. It is useful against other pests which hibernate about the leaf buds of fruit trees, as, for example, the pear-leaf blister-mite and the silvery mite of the peach, and in California Mr. Clark has shown that it is an entirely satisfactory remedy for the peach twig borer (*Anarsia lineatella* Zell.).

In addition to this range of usefulness against insect pests this wash has shown itself to be a valuable fungicide, notably for the peach leaf curl, sprayed trees being practically immune from this disease, so that the cost of treatment in the case of the peach is often more than made good by the fungicidal benefit alone. Later experience indicates its usefulness also as a winter application for apple scab and possibly for other plant diseases.

TIME TO SPRAY FOR SUCKING INSECTS.

For the larger plant-bugs and the aphides, or active plant-lice, and all other sucking insects which are present on the plants injuriously for comparatively brief periods, or at most during summer only, the treatment should be immediate, and if in the form of spray on the plants, at a strength which will not injure growing vegetation.

For scale insects and some others, as the pear *Psylla*, which hibernate on the plants, two or more strengths are advised with most of the liquid insecticides recommended, the weaker for summer applications and the more concentrated as winter washes. The summer washes for scale insects are most effective against the young, and treatment should begin with the first appearance of the larvæ in the spring or any of the later broods, and should be followed at intervals of seven days with two or three additional applications. The first brood, for the majority of species in temperate regions, will appear during the first three weeks in May. Examination from time to time with a hand lens will enable one to determine when the young of any brood appear.

The winter washes may be used whenever summer treatment can not be successfully carried out, and are particularly advantageous in the case of deciduous plants with dense foliage which renders a thor-

^a See Bul. 46, Bur. Ent., p. 54.

ough wetting difficult in summer, or with scale insects which are so irregular in the time of disclosing their young that many summer treatments would be necessary to secure anywhere near complete extermination. In the winter also, with deciduous trees, very much less liquid is required, and the spraying may be much more expeditiously and thoroughly done. In the case of badly infested trees, a vigorous pruning is advisable as a preliminary to treatment.

DUSTING AND SPRAYING APPARATUS.

POWDER DISTRIBUTERS.

For the application of powders the dusting bags already described (pp. 11-12) are very satisfactory for field work. Much more expensive and more rapid

machine distributors have been devised, but these are rarely used. For garden work some of the small powder bellows and blowers are excellent. These cost from \$2 to \$8.

LIQUID SPRAYERS.

For the application of poisons in liquid form the prime essential is an apparatus which will break up the liquid into a fine mist-like spray that will coat every leaf and every other part

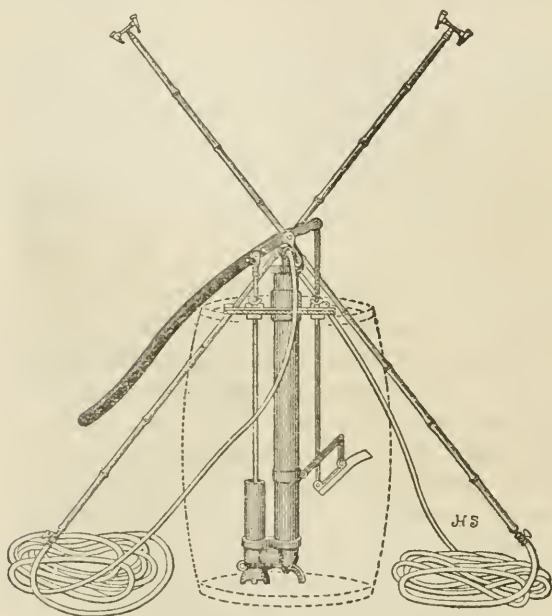


FIG. 3.—Barrel spray pump. (From Waite.)

of the plant as lightly as is compatible with thoroughness. The essential features of such an apparatus are the force pump, suitable hose, and nozzles or spray tips. The leading pump manufacturers now put out a large variety of spraying apparatus suited for all ordinary needs, including the small knapsack pumps, barrel and tank pumps, and geared and power sprayers. For limited indoor operations a hand atomizer or even a sprinkling can with fine rose tip may be made to do fair service.

The barrel pump.—This is the commonest form of spraying apparatus, and is supplied in many different styles; or, a suitable spray pump can be combined with an empty 50-gallon kerosene barrel without much difficulty. (See fig. 3.) This apparatus may be hauled about on a sled or in a wagon or a two-wheeled cart.

Tank outfits.—For larger operations it is much better to have a specially constructed rectangular or half-round spray tank of a capacity of 200 or 300 gallons. Such an apparatus enables an elevated platform to be mounted on the wagon and tank, greatly facilitating spraying of the higher parts of trees, as indicated in the accompanying illustration (fig. 4). The ideal sprayer for extensive work combines such a tank, with platform, with gasoline or steam power spray pump.

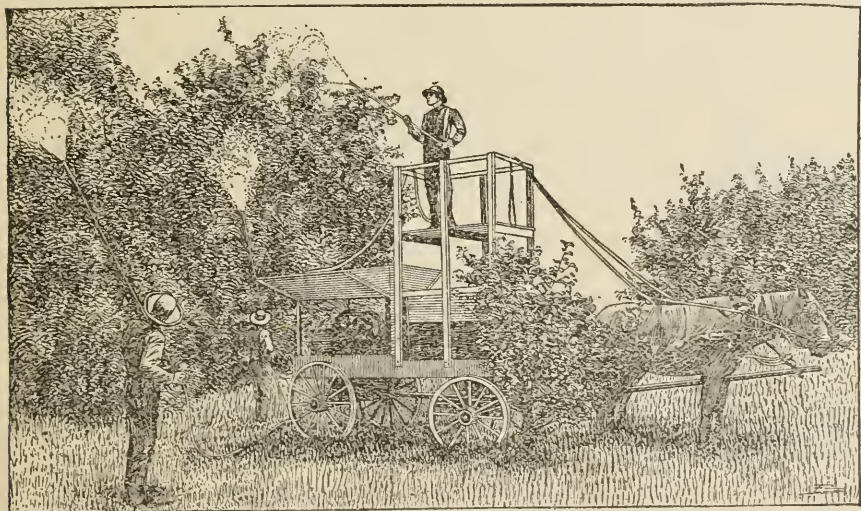


FIG. 4.—Power sprayer at work in apple orchard. (From Scott and Quaintance.)

Geared sprayers.—For low-growing regularly planted crops it is sometimes possible to use spraying apparatus which gets its power by means of a sprocket wheel from the axle of the wagon. Several types of spraying apparatus of this kind are on the market, suited especially for the treating of crops like potatoes and strawberries, and the spraying of vineyards. In orchards it is not often possible to have the wagon constantly in motion, and geared sprayers are not as a rule available.

Gas-pressure sprayers.—Some very successful spraying machines have been made which have as their motive power gas pressure. This pressure may be derived from compressed air or carbonic acid gas cylinders. It is an ideal way of applying liquid sprays, and has a

special applicability to oil-water mixtures (see p. 19). Ultimately this principle may come into much more general use.

Hose, nozzle, and agitator.—The hose and nozzle are two very essential elements of a good spraying apparatus. The very best three-eighths, one-fourth, or one-half inch 3-ply or 4-ply hose should be bought. A cheap or inferior hose will not stand the pressure and heavy wear of spraying. For orchard spraying a length of 25 feet is the least that should be used, and better 35 feet, and longer with large apparatus where it may be possible to spray more than one row at a time. Several lines of hose may be operated with a strong spray pump. Each line of hose should be supplied with an extension rod 8 or 10 feet long. This rod may be an ordinary bamboo pole into which a small brass tube is fitted carrying the nozzle, or the hose may terminate in a small gas pipe—a rather heavy device and useful for short length only.

Of the many types of nozzles which have been devised, the best is that known as the Vermorel (fig. 5). Where the power is sufficient, a double or even quadruple nozzle may be attached to each line of hose. Most of the nozzles on the market are inferior, and this special type should be insisted upon.

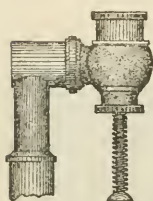


FIG. 5.—Vermorel
spray nozzle.
(From Walte.)

A very necessary feature of spray tanks is a device for keeping the liquid constantly agitated to keep up a uniform mixture or prevent the settling of the poison or solid constituents of the wash. This may be accomplished by constant stirring with a paddle.

Most of the spraying apparatus now on the market are provided with automatic agitators.

SELECTION OF SPRAYING OUTFIT.

For limited garden work or for the treatment of low plants a simple bucket pump can be used, which will cost about \$6, or the knapsack pump, costing about \$14.

For home orchards of small size a barrel pump with one line of hose will serve every purpose, the complete outfit costing \$12 to \$18.

For larger operations, with two lines of hose and nozzles, a barrel outfit, costing from \$25 to \$30, may be used.

Tank outfits, with double cylinder pumps suitable for an orchard of a thousand bearing trees, may be obtained at a cost of from \$75 to \$90.

The power sprayers are much more expensive, costing \$200 to \$300 or more.

DIRECTIONS FOR SPRAYING.

Thorough work in spraying must be done, or failure will result. To accomplish this, power sufficient to break up the liquid into a fine mist is essential. This makes it possible for the tree to be thoroughly and thinly wetted with the spray without waste, and the ideal application is to accomplish this without causing the liquid to collect in drops and fall from the tree. More of the spray is left on the leaves with a light spray than with a heavy application, which causes the globules to coalesce and a shower of drops to fall to the ground. To get a proper spray, it should be possible to produce a pressure of at least 75 pounds, or, with power outfits, of 125 to 150 pounds.

Fruit trees of average size or, if apple, such as would produce 10 or 15 bushels of fruit, will require from 3 to 7 gallons of spray to wet them thoroughly. For smaller trees, such as plum and cherry, 1 gallon to the tree may be sufficient. In spraying orchard trees and other fruit trees it will often be found convenient, especially with a smaller apparatus, to spray on each side half of each tree in a row at a time, and finish on the return.

A light rain will remove comparatively little of the poison, but a dashing rain may necessitate a renewal of the application.

HYDROCYANIC-ACID GAS TREATMENT.

The use of hydrocyanic-acid gas originated in southern California in work against citrus scale insects, and was perfected by a long period of experimentation by an agent of this Bureau, Mr. D. W. Coquillett. It is undoubtedly the most thorough method known of destroying scale insects and especially is it the best treatment for citrus trees, the abundance of foliage and nature of growth of which render thorough spraying difficult, but, on the other hand, enable the comparatively heavy tents employed in fumigation to be thrown or drawn over the trees rapidly without danger of breaking the limbs. One good gassing is usually the equivalent of two or three sprayings, the gas penetrating to every particle of the surface of the tree and often effecting an almost complete extermination, rendering another treatment unnecessary for two years or more. (See fig. 6.)

The gas treatment is just as effective against scale insects on deciduous orchard fruit trees, as has been demonstrated by a good deal of work done in the East, notably in Maryland by Professor Johnson; but the difficulty and expense of the treatment as compared with the value of the crop protected makes it as a rule prohibitive in the case of deciduous fruits. This does not apply, however, to nursery stock, which may be brought together compactly and treated in mass in

fumigating rooms or houses. The general spread of the San Jose scale in the East has made such fumigation of nursery stock, even when infestation is not shown or suspected, a necessary procedure before shipment or sale, to give the utmost assurance of safety to the purchaser. Similarly this gas is the principal agency employed in disinfecting plant material coming from abroad, and will be the chief agency for such work wherever quarantine regulations prevail.

Another very important use for hydrocyanic-acid gas is as a means of controlling insect pests in greenhouses and cold frames. The process is a special one, however, and entails considerable variation, owing to the wide range of plants to be considered. The details of the process are given in a special publication of the Bureau of Entomology (Circular No. 37), which will be supplied to anyone interested.

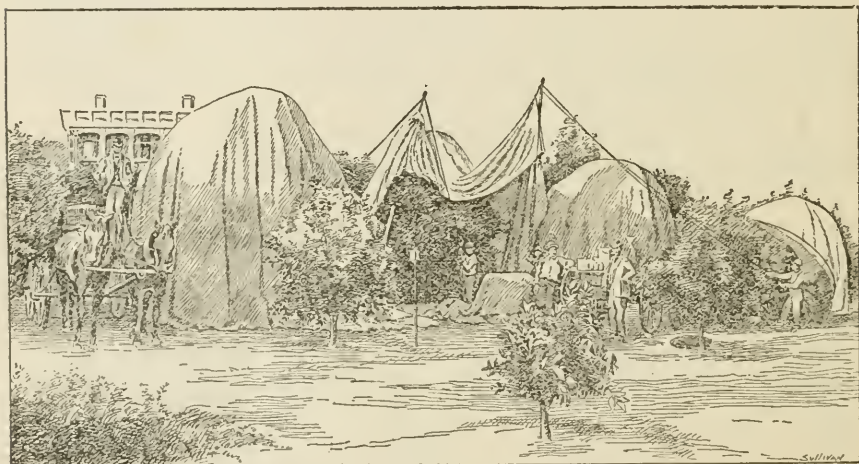


FIG. 6.—Tenting trees for gas treatment, San Diego, Cal. (Author's illustration.)

A more recent use for this gas is in disinfecting houses of insect pests and vermin. The details of this treatment are given in Circular 46, revised edition, of the Bureau of Entomology.

In all work with hydrocyanic-acid gas, its extremely poisonous nature must be constantly kept in mind and the greatest precautions must be taken to avoid inhaling it.

FUMIGATION OF NURSERY STOCK.

For the fumigation of nursery stock or imported plant material in a dormant or semidormant condition, a building or room should be provided, which can be closed practically air-tight, and it should be fitted with means of ventilation above and at the side, operated from without, so that the poisonous gas can be allowed to escape without

the necessity of anyone entering the chamber. The gas is generated by combining potassium cyanide, sulphuric acid, and water. The proportions of the chemicals are as follows: Refined potassium cyanide (98 per cent), 1 ounce; commercial sulphuric acid, 1 ounce; water, 3 fluid ounces to every hundred cubic feet of space in the fumigating room. For comparatively green or tender material the same amounts may be used to 150 cubic feet of space.

The generator of the gas may be any glazed earthenware vessel of 1 or 2 gallons capacity and should be placed on the floor of the fumigating room, and the water and acid necessary to generate the gas added to it in the order named. The cyanide should be added last, preferably in lumps the size of a walnut, and the premises promptly vacated and the door made fast. Treatment should continue forty minutes.

ORCHARD FUMIGATION.

The methods of fumigating citrus stock in California are now (1908) being given a thorough investigation by this Bureau. As already noted, the gas process has been a leading method in California for more than twenty years, but the results, while normally good, have not always been satisfactory. The object of the investigation now under way is to thoroughly standardize the process; in other words, (1) to determine the proper strength to be used for the different scale pests under different climatic conditions, and also under the different seasonal conditions of the tree; (2) to determine the physiological effect, if any, on the tree and fruit; and (3) to perfect the mechanical means of handling tents and generating the gas, and determine the proper quantity and quality of chemicals to use. The results of this investigation will be the basis of a special report on gas fumigation, and will probably modify somewhat the directions given below, which are reproduced from the previous edition of this bulletin.

The fumigation for the white fly in Florida is a special problem and has been under investigation by this Bureau for two years. The results of this investigation, including general directions for fumigation, will be given in Bulletin No. 76.

Amounts of chemicals to use.—The amounts of chemicals used vary with the size of the tree and, as now employed in California, are considerably in excess of the amounts recommended as recently as 1898. The gas treatment was first chiefly used against the black scale and at a season of the year when these scales were all in a young stage and easily killed. The effort is now made not only to kill the black scale, but also the red and purple scales, and to do more effective work than formerly against the black scale. The amounts of chemicals ordinarily advised and commonly employed in Los Angeles,

Orange, and some other counties in southern California are indicated in the subjoined table, published by the horticultural commissioners of Riverside County, Cal.

TABLE 1.—*Amounts of chemicals and water ordinarily used for trees of different sizes.*

Height of tree.	Diameter of tree.	Water.	Cyanide, C. P., 98 per cent.	Sulphuric acid, 66 per cent.
<i>Feet.</i>	<i>Feet.</i>	<i>Ounces.</i>	<i>Ounces.</i>	<i>Ounces.</i>
6	4	2	1	1
8	6	3	1½	1½
10	8	5	2½	2½
12	14	11	5	5½
16	16	17	8	9
20	16-20	22	10	12
20-24	18-23	30	14	16
24-30	20-28	34	16	18
30-36	25-30	52	24	28

The proportions here recommended are thoroughly effective for the black scale at the proper season, and measurably effective also for the California red scale and the purple scale. Where the treatment is designed to be one of extermination for these latter scale pests, from one-third to one-half more of cyanide and acid is employed, as indicated by the subjoined table, furnished by Mr. G. Havens, of Riverside. The amounts here recommended may be employed also for compact trees with dense foliage or in moist coast regions where stronger doses are needed.

TABLE 2.—*Excessive amounts of chemicals used for absolute extermination of scale insects.^a*

Height of tree.	Diameter through foliage.	Water.	Sulphuric acid.	Cyanide.	Time to leave tent on tree.
<i>Feet.</i>	<i>Feet.</i>	<i>Fluid ozs.</i>	<i>Fluid ozs.</i>	<i>Ounces.</i>	<i>Minutes.</i>
6	3-4	3	1½	3-1	20
8	5-6	6	2½	4-2	30
10	7-10	15	5-6	4-5	35-40
12	9-12	20-30	7-9	5½-7½	40
14	12-14	30-35	9-12	8-10	40
16	12-15	35-40	12-14	10-12	40
18	14-16	45-55	15-18	12-15	40-50
20	16-18	60-70	20-22	16-20	45-50
22	16-18	70-75	22-25	20	50
24	18-20	75-80	25-30	22-25	50
27	20-24	85-100	30-36	25-32	60
30	20-23	100-110	36-44	32-38	60

^aA fumigation of the orangery of the Department, December 3, 1900, demonstrated that 0.15 of a gram of cyanide to the cubic foot, or a little more than half an ounce to the hundred cubic feet, is completely exterminative of scale insects, effectually killing the eggs, even of the black, purple, and other scales. The strength mentioned is that ordinarily recommended for violet houses, and the results are scarcely comparable to the proportions recommended in Tables 1 and 2, for the reason that in these tables the amount of cyanide is greatly lessened with larger trees, and, furthermore, that the orangery probably retained the gas more effectually than would be the case with cloth tents. Nevertheless, it is interesting to know that a comparatively inconsiderable strength of cyanide, when applied under the best conditions, will prove thoroughly effective against the eggs as well as the insects in all stages.

The duration of the treatment indicated in the second table varies with the size of the tree, but in general at least forty minutes should be allowed.

In Florida fumigation for the white fly can be successfully practiced only during the short period in winter when the insect does not occur in the winged stage. This period covers from two and a half to three months, namely, December, January, and February, varying with the climatic conditions of different years. This is the dry season for Florida, and the trees are in a dormant condition, with the leafage well matured and hardened, and it is possible to apply a greater strength than would be safe under California conditions. The strength recommended is approximately the same as for deciduous nursery stock, viz, 1 ounce of cyanide to 100-115 cubic feet of space, with a duration of 40 minutes.

General directions.—In the fumigation of growing stock, citrus or other, the treatment consists in inclosing the tree with a tent and filling the latter with poisonous fumes generated in the same way as described for nursery stock except that less of the chemicals is used. The treatment is made at night for trees in foliage, which includes all work in citrus orchards, to avoid the much greater likelihood of injury to tender foliage in the sunlight. The vessels for setting off the charges of cyanide and acid may be, for small doses, any ordinary earthenware jars. For large trees requiring heavy doses, tall wooden pails have proved more satisfactory, two generators being employed for the very largest trees.

It is important that the water be put in the vessel first, then the acid, and lastly the cyanide. If the water and cyanide are put in the vessel first and the acid poured in afterwards, there is danger of an explosion which will scatter the acid and burn the tents and the operator. In the spring, when the trees are tender with new growth, and in early fall when the oranges are nearly grown and the skins are likely to be easily marred, and also with young trees, it is advisable to add one-third more water than ordinarily used, or to add the cyanide in larger lumps. This causes the gas to generate more slowly and with less heat, and, if the tents are left over the trees a third longer, the effectiveness of the treatment will not be lessened. The person handling the chemicals should always have an attendant with a lantern, to hold up the tent and enable the cyanide to be quickly dropped into the generator, and to facilitate the prompt exit of the operator.

Trees are fumigated for the black scale in southern California in October, or preferably in November. The red and other scales may be treated with gas at any time, but preferably at the season already indicated. In California most of the work is done by contract, or

under the direct supervision of the county horticultural commissioners, in some cases the tents and material being furnished at a merely nominal charge, together with one experienced man to superintend the work, while a crew of four men operate the tents, the wages of the director and men being paid by the owner of the trees.

Construction and handling of tents.—The tents now employed are of

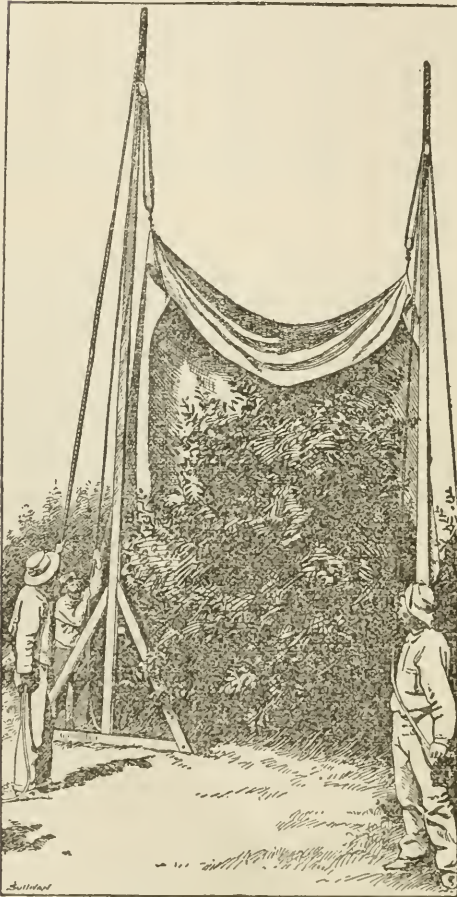


FIG. 7.—Method of hoisting sheet tent.
(After Craw.)

two kinds, the "sheet" tent of octagonal shape for large trees, and the "ring" tent for trees under 12 feet in height. The ring tents, or, as they are also called, the bell tents, are bell-shaped and have a hoop of half-inch gas pipe fastened within a foot or so of the opening. Two men can easily throw one of these tents over a small tree. An equipment of 36 or 40 ring tents can be handled by four men. They are rapidly thrown over the trees by the crew, and the director follows closely and introduces the chemicals. By the time the last tent has been adjusted the first one can be removed and taken across to the adjoining row. An experienced crew, with one director, can treat 350 to 400 5-year-old trees, averaging 10 feet in height, in a single night of eleven or twelve hours. The cost under such conditions averages about 8 cents a tree.

With large trees the large sheet tents are drawn over them by means of uprights and pulley blocks. Two of these sheets are necessary for very large trees, the first being drawn halfway over and the second drawn up and made to overlap the first. In the case of trees from 24 to 30 years old and averaging 30 feet in height, about 50 can be treated in a night of ten or twelve hours with an equipment of 12 or 15 tents, the cost being

about 75 cents per tree. It is not practicable to treat trees above 30 feet in height.

The handling of the bell tents is simple and needs no further description, but the large tents are not so easily operated, and the method of adjusting the great flat octagonal sheets over the trees, while simple enough when once understood, warrants a description. The machinery employed consists of two simple uprights, with attached blocks and tackle (fig. 7). The uprights are about 25 feet high, of strong Oregon pine, 2 by 4 inches, and are provided at the bottom with a braced crossbar to give them strength and to prevent their falling to either side while the tent is being raised. A guy rope is attached to the top of each pole and held to steady it by a member of the crew stationed at the rear of the tree. The tent is hoisted by means of two ropes 70 feet long, which pass through blocks, one fixed at the top of the pole and the other free. The tent is caught near the edge by taking a hitch around some solid object, such as a green orange, about which the cloth is gathered. By this means the tent may be caught anywhere without the trouble of reversing and turning the heavy canvas to get at rings or other fastenings attached at particular points. The two remaining members of the operating crew draw the tent up against and over one side of the tree by means of the pulley ropes sufficiently to cover the other side of the tree when the tent falls. The poles and tent together are then allowed to fall forward, leaving the tent in position. Sufficient skill is soon acquired to carry out rapidly the details of this operation, so that little time is lost in transferring the tents from tree to tree, even when the trees approximate the limit in height. A single pair of hoisting poles answers for all the tents used.

Some of the tents employed are of great size, one described by Mr. Havens having a diameter of 76 feet. It is constructed of a central piece 50 feet square, of 10-ounce army duck. Four triangular side pieces or flaps of 8-ounce duck, 10 feet wide in the middle, are strongly sewed to each side of the central sheet, forming an octagonal sheet 70 feet in diameter. About the whole sheet is then sewed a strip of 6-ounce duck, 1 yard wide. The tent is handled by means of ropes and pulleys. A $1\frac{1}{2}$ -inch manila rope is sewed about the border of the central piece in an octagonal pattern. Rings are attached to this rope at each of the eight corners thus formed, and also on either side of the tent. To these rings the pulley ropes are fastened, and the tent is elevated over the trees and handled very much as indicated in fig. 7.

The canvas for the tents, blue or brown drilling or 8 to 10 ounce duck, may be rendered comparatively impervious to the gas by painting lightly with boiled linseed oil. This has the objection, however, of stiffening the fabric and adding considerably to its weight; it also frequently leads to its burning by spontaneous combustion unless carefully watched until the oil is dry. A much better material

than oil is found in a product obtained from the leaves of the common prickly pear cactus (*Opuntia engelmanni*), which grows in abundance in the Southwest. The liquor is obtained by soaking chopped-up leaves in water for twenty-four hours. It is given body and color by the addition of glue and yellow ocher or venetian red, and is applied to both sides of the canvas and rubbed well into the fiber of the cloth with a brush.

Some practical experience is necessary to fumigate successfully, and it will therefore rarely be wise for anyone to undertake it on a large scale without having made preliminary experiments.

BISULPHID OF CARBON VAPOR.

In line with the use of hydrocyanic-acid gas is the employment of the vapor of bisulphid of carbon to destroy insects on low-growing plants, such as the aphides on melon and squash vines. The treatment, as successfully practiced by Professors Garman and Smith, consists in covering the young vines with small tight boxes 12 to 18 inches in diameter, of either wood or paper, and introducing under each box a saucer containing one or two teaspoonfuls (1 or 2 drams) of the very volatile liquid bisulphid of carbon. The vines of older plants may be wrapped about the hill and gathered in under larger boxes or tubs, and a greater, but proportional, amount of the liquid used. The covering should be left over the plants from three-quarters of an hour to an hour, and with 50 to 100 boxes a field may be treated with comparative rapidity.

Bisulphid of carbon has proved also to be the most effective means of disinfecting grape cuttings suspected of being infested with phylloxera.^a The cuttings are inclosed in a tight barrel or fumigating box, and the bisulphid of carbon, poured out in a shallow dish, is put on top of the cuttings. An ordinary saucerful of the chemical is enough for a box 3 feet cube. The treatment lasts from forty-five to ninety minutes. This is a pretty strong fumigation, but the dormant condition of the cuttings makes this possible.

REMEDIES FOR SUBTERRANEAN INSECTS.

Almost entire dependence is placed on the caustic washes, or those that act externally, for insects living beneath the soil on the roots of plants, including both sucking and biting insects, prominent among which are the white grubs, maggots in roots of cabbage, radishes, onions, etc., cutworms, wireworms, apple and peach root-aphides, the grape phylloxera, and many others.

The insecticide must be one that will go into solution and be carried down by water. Of this sort are the kerosene emulsions and resin

^a Bul. 192, Cal. Agr. Exp. Sta., 1907.

wash—the former preferable—the potash fertilizers, muriate and kainit, and bisulphid of carbon. The simple remedies are applications of strong soap or tobacco washes to the soil about the crown; or soot, ashes, or tobacco dust buried about the roots; also similarly employed are lime and gas lime. Submersion, wherever the practice of irrigation or the natural conditions make it feasible, has proved of the greatest service against the phylloxera.

HOT WATER.

As a means of destroying root-aphides, and particularly the woolly aphid of the apple, the most generally recommended measure hitherto is the use of hot water, and this, while being both simple and inexpensive, is thoroughly effective, as has been demonstrated by practical experience. Water at nearly the boiling point may be applied about the base of young trees without the slightest danger of injury to the trees, and should be used in sufficient quantity to wet the soil thoroughly to a depth of several inches, as the aphides may penetrate nearly a foot below the surface. To facilitate the wetting of the roots and the extermination of the aphides, as much of the surface soil as possible should be first removed.

By a hot-water bath slightly infested stock can be easily freed of the aphides at the time of its removal from the nursery rows. The soil should be dislodged and the roots pruned, and in batches of a dozen or so the roots and lower portion of the trunks should be immersed for a few seconds in water kept at a temperature of 130° to 150° F. A strong soap solution similarly heated or a fifteen times diluted kerosene emulsion will give somewhat greater penetration and be more effective, although the water alone at the temperature named should destroy the aphides.

Badly infested nursery stock should be destroyed, since it would be worth little even with the aphides removed.

TOBACCO DUST.

Some very successful experiments conducted by Prof. J. M. Stedman demonstrated the very satisfactory protective, as well as remedial value of finely ground tobacco dust against the woolly aphid. The desirability of excluding the aphid altogether from nursery stock is at once apparent, and this Professor Stedman shows to be possible by placing tobacco dust freely in the trenches in which the seedlings or grafts are planted and in the orchard excavations for young trees. Nursery stock may be continuously protected by laying each spring a line of the dust in a small furrow on either side of the row and as close as possible to the tree, and covering loosely with earth. For large trees, both for protection and the destruction of existing aphides, from 2 to 5 pounds of the dust should be distributed from the base outward to a distance of 2 feet, first removing the surface

soil to a depth of from 4 to 6 inches. The tobacco kills the aphides by leaching through the soil, and acts for a year or so as a bar to reinfestation. The dust is a waste product of tobacco factories, costs about 1 cent per pound, and possesses the additional value of being worth fully its cost as a fertilizer.

Since its early recommendation marked success has been reported from the use of tobacco dust. A notable instance is that given by Mr. M. B. Waite, of the Bureau of Plant Industry, who applied a ton of tobacco waste, costing \$25, in his orchard, with the result of entirely renewing the vigor of his trees and producing a strong stubby growth of twigs. A peck of tobacco dust was placed about each of his larger trees in a circle of 2 or 3 feet around the trunk, and a slightly smaller amount about trees from one to three years old.

KEROSENE EMULSION AND RESIN WASH.

Either the kerosene-and-soap emulsion or the resin wash, the former diluted fifteen times and the latter at the strength of the winter mixture, are used to saturate the soil about the affected plants and either left to be carried down by the action of rains or washed down to greater depths by subsequent waterings.

For the grape phylloxera or the root-aphis of the peach or apple, make excavations 2 or 3 feet in diameter and 6 inches deep about the base of the plant and pour in 5 gallons of the wash. If not a rainy season, a few hours later wash down with 5 gallons of water and repeat with a like amount the day following. It is better, however, to make this treatment in the spring, when the more frequent rains will take the place of the waterings.

For root-maggots enough of the wash is put at the base of the plant to wet the soil to a depth of 1 to 2 inches, preferably followed after an hour with a like amount of water.

For white grubs in strawberry beds or in lawns the surface should be wetted with kerosene emulsion to a depth of 2 or 3 inches, following with copious waterings to be repeated for two or three days. The larvæ go to deeper and deeper levels and eventually die.

POTASH FERTILIZERS.

For white grubs, wireworms, cutworms, corn root-worms, and like insects, on the authority of Prof. J. B. Smith, either kainit or the muriate of potash—the former being the better—are broadcasted in fertilizing quantities, preferably before or during a rain, so that the material is dissolved and carried into the soil at once. These not only act to destroy the larvæ in the soil, but are deterrents, and truck lands constantly fertilized with these substances are noticeably free from attacks of insects. This, in a measure, results from the increased vigor and greater resisting power of the plants, which of itself

more than compensates for the cost of the treatment. The value of these fertilizers against the wireworms is, however, questioned by Prof. J. H. Comstock.

For the root-aphis of peach and apple, work the fertilizer into the general surface of the soil about the trees, or put it into a trench about the tree 2 feet distant from the trunk.

For cabbage and onion maggots, apply in little trenches along the rows at the rate of 300 to 500 pounds to the acre, and cover with soil.

These fertilizers (and the nitrate of soda is nearly as good) are also destructive to the various insects which enter the soil for hibernation or to undergo transformation.

BISULPHID OF CARBON.

This is the great French remedy for the phylloxera, 150,000 acres being now subjected to treatment with it, and applies equally well to all other root-inhabiting aphides. The treatment is made at any season except the period of ripening of the fruit and consists in making holes about the vines 1 foot to 16 inches deep and pouring into each about one-half ounce of the bisulphid, and closing the holes with the foot. The injections are made about $1\frac{1}{2}$ feet apart, and not closer to the vines than 1 foot. It is better to use a large number of small doses than a few large ones. Hand injectors and injecting plows are employed in France to put the bisulphid into the soil about the vines, but a short stick or iron bar may take the place of these injectors for limited tracts.

The use of bisulphid of carbon for the woolly aphis is the same as for the grape root-aphis or phylloxera. It should be applied in two or three holes about the tree to a depth of from 6 to 12 inches and not closer than $1\frac{1}{2}$ feet to the tree. An ounce of the chemical should be introduced into each hole, which should be immediately closed.

For root-maggots a teaspoonful is poured into a hole near the base of the plant, being covered as above.

For ant nests an ounce of the substance is poured into each of several holes made in the space occupied by the ants, the openings being then closed; or the action is made more rapid by covering with a wet blanket for ten minutes and then exploding the vapor at the mouth of the holes with a torch, the explosion driving the fumes more thoroughly through the soil.

SUBMERSION.

This very successful means against the phylloxera is now practiced over some 75,000 acres of vineyards in France which were once destroyed by the grape root-aphis, and the production and quality of fruit has been fully restored. In this country it will be particularly available in California and in all arid districts where irrigation is

practiced; otherwise it will be too expensive to be profitable. The best results are secured in soils in which the water will penetrate rather slowly, or from 6 to 18 inches in twenty-four hours; in loose, sandy soils it is impracticable on account of the great amount of water required. Submersion consists in keeping the soil of the vineyard flooded for from eight to twenty days after the fruit has been gathered and active growth of the vine has ceased, or during September or October, but while the phylloxera are still in active development. Early in September eight to ten days will suffice; in October fifteen to twenty days, and during the winter, forty to sixty days. Supplementing the short fall submergence a liberal July irrigation, amounting to a forty-eight hour flooding, is customary to reach any individuals surviving the fall treatment, and which in midsummer are very susceptible to the action of water.

To facilitate the operation, vineyards are commonly divided by embankments of earth into square or rectangular plats, the former for level and the latter for sloping ground, the retaining walls being protected by coverings of reed grass, etc., during the first year, or until they may be seeded to some forage plant.

This treatment will destroy many other root-attacking insects and those hibernating beneath the soil, and, in fact, is a very ancient practice in certain oriental countries bordering the Black Sea and the Grecian Archipelago.

REMEDIES FOR INSECTS AFFECTING GRAIN AND OTHER STORED PRODUCTS.

GENERAL METHODS OF TREATMENT.

The chief loss from insects of this class is to grains in farmers' bins, or grain or grain products in stores, mills, and elevators, although in the warmer latitudes much injury results from infestation in the field between the ripening of the grain and its storage in bins or granaries. Fortunately, the several important grain insects are amenable to like treatment. Aside from various important preventive operations, such as, in the South, prompt thrashing of grain after harvesting, the thorough cleansing of bins before refilling, removal of waste harboring insects from all parts of granaries and mills, and care to prevent the introduction of "weeviled" grain, there are four valuable remedial measures, viz, agitation of the grain, heating, dosing with bisulphid of carbon, and fumigating with sulphur dioxide.

The value of agitating or handling grain is well known, and whenever, as in elevators, grain can be transferred or poured from one bin into another, grain pests are not likely to trouble. The benefit will depend upon the frequency and thoroughness of the agitation. In

France machines for shaking the grain violently have been used with success. Winnowing weeviled grain is also an excellent preliminary treatment.

Raising the temperature of the grain in closed retorts or revolving cylinders to 130° to 150° F. will kill the inclosed insects if continued for three to five hours, but is apt to injure the germ, and is not advised in case of seed stock. The simplest and most effective remedies are the use of either bisulphid of carbon or sulphur dioxide.

BISULPHID OF CARBON.^a

Character and method of application.—This is a colorless liquid with very offensive odor, which, however, passes off completely in a short time. It readily volatilizes, and the vapor, which is very deadly to insect life, is heavier than air and settles and fills any compartment or bin in the top of which the liquid is placed. It may be distributed in shallow dishes or tins or in saturated waste on the top of grain in bins, and the gas will settle and permeate throughout the mass of the grain. In large bins, to hasten and equalize the operation, it is well to put a quantity of the bisulphid in the center of the grain by thrusting in balls of cotton or waste tied to a stick and saturated with the liquid, or by means of a gas pipe loosely plugged at one end, down which the liquid may be poured and the plug then loosened with a rod. Prof. H. E. Weed reports that in Mississippi the chemical is commonly poured directly onto the grain. In moderately tight bins no further precaution than to close them well need be taken, but in open bins it will be necessary to cover them over with a blanket to prevent the too rapid dissipation of the vapor. The bins or buildings should be kept closed from twenty-four to thirty-six hours, after which a thorough airing should be given them.

Limited quantities at a time may often be advantageously subjected to treatment in small bins before being placed for long storage in large masses, and especially whenever there is danger of introducing infested grain.

The bisulphid is applied at the rate of 1 pound to the ton of grain, or a pound to a cubic space 10 feet on a side.

In the case of mills, elevators, or larger granaries the application may be best made on Saturday night, leaving the building closed over Sunday, with a watchman without to see that no one enters and to guard against fire. The bisulphid should be first distributed in the upper story, working downward as rapidly as possible to avoid the settling vapor, using the substance very freely in waste or dishes at all points of infestation and over bins throughout the building. If the building be provided with an exterior means of descent (such as

^a See Farmers' Bulletin No. 145, Carbon Bisulphid as an Insecticide.

a fire escape) it would be preferable to begin with the lower story and work upward.

This insecticide may also be used in other stored products, as peas, beans, etc., and very satisfactorily where the infested material can be inclosed in a tight can, chest, or closet for treatment. It may also be employed to renovate and protect wool or similar material stored in bulk.

The bisulphid costs, in 50-pound cans, 10 cents per pound, and in small quantities, of druggists, 25 to 35 cents per pound.

Caution.—The bisulphid may be more freely employed with milling grain than with that intended for seeding, since, when used excessively, it may injure the germ. It must always be remembered that the vapor is highly inflammable and explosive, and that no fire or lighted cigars, etc., should be in the building during its use. If obtained in large quantities it should be kept in tightly closed vessels and away from fire, preferably in a small outbuilding.

While this gas is not especially dangerous to human beings, care should be taken to avoid unnecessary inhalation. It has a slight suffocating effect, and if inhaled for some time produces dizziness, which should be a warning to the operator that it is time to seek fresh, pure air.

SULPHUR DIOXID.

The fumes of burning sulphur, namely, sulphur dioxid, with some sulphur trioxid, have long been one of the standard insecticide gases for the destruction of insect pests in rooms or dwellings, and notably for the bedbug (*Cimex lectularius* L.). Doctor Stiles, of the Public Health and Marine-Hospital Service, reports very successful fumigation and disinfection of frame cottages at a seaside resort for bedbug infestation by burning sulphur at the rate of 2 pounds of stick sulphur for each 1,000 cubic feet of space. Sulphur candles for such fumigation are a standard supply material to be purchased anywhere. Sulphur fumes are also employed for disinfection from disease germs, and also in the more recent yellow-fever work for the destruction of mosquitoes in dwellings. The chief objection to the sulphur fumigation arises from the strong bleaching action of the fumes in the presence of moisture and their powerful destructive action on vegetation.

For the disinfection of ships and ships' cargoes, particularly of grain, sulphur dioxid, under the name of "Clayton gas," is now being extensively employed. To determine its efficiency and its effect on the grains treated, a considerable series of experiments was conducted by the Bureau.^a These experiments showed that sulphur dioxid, under pressure such as can be maintained in an air-tight compartment or in the hold of a ship, has great penetrating power and is very efficient as a means of destroying all kinds of insects. The germinating

^a Bul. 60, Bur. Ent., U. S. Dept. Agric., pp. 139-153. 1906.

power of seeds is quickly destroyed, but no injury results to the feeding or cooking quality of cereals. It can not be employed in the case of living plants, nor with moist fruits or products, such as apples or bananas. The best results in the case of insects infesting grains and seeds, such as Calandra and Bruchus, which are often inclosed in the seeds, were obtained by the use of a low percentage (1 to 5 per cent of gas) for a period of twelve to twenty-four hours. Employed in this way the gas is a very effective means of disinfecting stored grain or similar products not intended for planting, and has the additional advantage of entirely eliminating the danger of explosion and fire.

GENERAL CONSIDERATIONS ON THE CONTROL OF INSECTS.

ADVANTAGE OF PROMPT TREATMENT.

The importance of promptness in the treatment of plants attacked by insects can not be too strongly insisted upon. The remedy often becomes useless if long deferred, the injury having already been accomplished or gone beyond repair. If, by careful inspection of plants from time to time, the injury can be detected at the very outset, treatment is comparatively easy and the result much more satisfactory. Preventive work, therefore, should be depended on as much as possible, rather than remedial treatment later; the effort being to forestall any serious injury rather than to patch up damage which neglect has allowed to become considerable.

KILLING INSECTS AS A PROFESSION.

It may often happen that the amount of work in a community is sufficient to induce one or more persons to undertake the treatment of plants at a given charge per tree or per gallon of the insecticide employed. Where this is the case, and the contracting parties are evidently experienced and capable, it is frequently more economical in the end to employ such experienced persons, especially when a guarantee is given, rather than attempt to do the work one's self with the attending difficulty of preparing insecticides and securing apparatus for work on a comparatively small scale. In California this is a common practice, and also in some of our Eastern cities, and has worked excellently.

DETERMINATION OF THE RESULT OF TREATMENT.

It is often of importance to know when and how to determine the effect of any treatment applied directly to insects exposed on the surface of plants. In the case of scale insects, especially during the dormant condition in winter, the response to insecticides is very slow and gradual. The scale larvæ, or any young scales during the growing season, are killed in a few minutes, or a few hours at furthest, just as any other soft-bodied insect, but the mature scale does not usually

exhibit the effects of the wash or gas for some time. Little can be judged, ordinarily, of the ultimate results before two weeks, and it is often necessary to wait one or even two months to get final conclusions. In the case of liquid washes the slow progressive death of the scales is apparently due to the gradual penetration of the insecticide, and also to the softening and loosening of the scale itself, enabling subsequent weather conditions of moisture and cold to be more fatal.

With such biting insects as caterpillars and slug worms, after treatment with arsenicals or other poisons death rapidly follows, the time being somewhat in proportion to the size of the larvæ and their natural vigor. Soft-bodied larvæ, such as the slug worms and very young larvæ of moths and beetles or other insects, are killed in a day or two. Large and strong larvæ sometimes survive the effect of poison for eight or ten days, and leaf-feeding beetles will often fly away and perish from the poison in their places of concealment.

Many larvæ or other forms of leaf-feeding insects, after taking one or two meals of poisoned foliage, will remain in a semitorpid and diseased condition on the plants for several days before they finally succumb. The protection to the plant, however, is just as great as though they had died immediately, but misapprehension may often arise and the poison may be deemed to have been of no service.

The complete extermination of insects on plants is often a very difficult, if not an impossible undertaking. This is especially true of scale insects. In California even, where the work against these enemies of fruits has been most thorough and successful, experience has shown that the best that can be done is a practical elimination of the scale for the time being, and it is often necessary to repeat the treatment every year or two. In exceptional cases once in three years suffices. With leaf-feeding insects it is often possible to effect complete extermination with the use of arsenical poisons. Such sucking insects as aphides may also be completely exterminated. But in general all applications or methods of treatment must be recognized, more or less, as a continuous charge on the crop, as much so as are the ordinary cultural operations.

CONTROL OF INSECTS BY CULTURAL METHODS.

It is much easier to ward off an attack of insects or to make conditions unfavorable for their multiplication than to destroy them after they are once in possession; and in controlling them, methods and systems of farm and orchard culture have long been recognized as of the greatest value, more so even than the employment of insecticides, which, in most cases, can only stop an injury already begun. Insects thrive on neglect, multiply best in land seldom or never cultivated, and winter over in rubbish, prunings, or the undisturbed soil about their food plants, and become, under these conditions, more numerous

every year. It is a fact of common observation that it is the neglected farm, vineyard, or orchard filled with weeds or wild growth which is certain to be stocked with all the principal insect enemies; and, on the other hand, thorough and constant culture, with the removal and burning of prunings, stubble, and other waste, the collection and destruction of fallen and diseased fruit, and the practice, where possible, of fall plowing to disturb the hibernating quarters of field insects, will almost certainly be accompanied by comparative immunity from insect pests.

The vigor and healthfulness of plant growth has also much to do with freedom from insect injury. Strong, healthy plants seem to have a native power of resistance which renders them, in a measure, distasteful to most insects, or at least able to throw off or withstand their attacks. A plant already weakened from any cause, however, seems to be especially sought after, is almost sure to be the first affected, and furnishes a starting point for general infestation. Anything, therefore, which aids good culture in keeping plants strong and vigorous, such as the judicious use of fertilizers, will materially assist in preventing injury.

The constant cropping of large areas of land year after year to the same staple is largely responsible for the excessive loss from insects in this country as compared with European countries, because this practice furnishes the best possible conditions for the multiplication of the enemies of such crops. A most valuable cultural means, therefore, is a system of rotation of crops which will prevent the gradual yearly increase of the enemies of any particular staple by the substitution every year or two of other cultures not subject to the attacks of the insect enemies of the first.

With such insects as the Hessian fly, the squash borers, and many others which have regular times of appearance, much can be done by the planting of early or late varieties or by deferring seeding so as to avoid the periods of excessive danger. Wherever possible, varieties should be selected which experience has shown to be resistant to insect attack. Familiar illustrations of such resistant varieties in all classes of cultivated plants will occur to every practical man, and a better instance of the benefit to be derived from taking advantage of this knowledge can not be given than the almost universal adoption of resistant American vines as stocks for the regeneration of the vineyards of France destroyed by the phylloxera and for the similarly affected vineyards of European grapes in California.

In the case of stored-grain pests, particularly the Angoumois moth, or so-called "fly weevil," the chief danger in the South occurs while the grain is standing in shock or stack, after harvesting, during which period the insects have easy access to it. This source of infestation may be avoided by thrashing grain promptly after harvesting and storing it in bulk. This will prevent injury to more than the sur-

face layer, as the insects are not likely to penetrate deeply into the mass of the grain.

These general notes are by no means new, but their importance justifies their repetition, as indicating the best preventive measures in connection with the remedial ones already given.

THE PROFIT IN REMEDIAL MEASURES.

The overwhelming experience of the past twenty years makes it almost unnecessary to urge, on the ground of pecuniary returns, the adoption of the measures recommended in the foregoing pages against insects. To emphasize the value of such practice it is only necessary to call attention to the fact that the loss to orchard, garden, and farm crops frequently amounts to from 15 to 75 per cent of the entire product, and innumerable instances could be pointed out where such loss has been sustained year after year, while now, by the adoption of remedial measures, large yields are regularly secured with an insignificant expenditure for treatment. It has been established that in the case of the apple crop spraying will protect from 50 to 75 per cent of the fruit which would otherwise be wormy, and that in actual marketing experience the price has been enhanced from \$1 to \$2.50 per barrel, and this at a cost of only about 10 cents per tree for labor and material. This is especially true of regions where the codling moth has but one full brood annually.

In the case of one orchard in Virginia, only one-third of which was sprayed, the result was an increase in the yield of sound fruit in the portion treated of nearly 50 per cent, and an increase of the value of this fruit over the rest of 100 per cent. The loss from not having treated the other two-thirds was estimated at \$2,500. The saving to the plum crop and other small fruits frequently amounts to the securing of a perfect crop where otherwise no yield whatever of sound fruit could be secured.

An illustration in the case of field insects may also be given where, by the adoption of a system of rotation, in which oats were made to alternate with corn, the owner of a large farm in Indiana made a saving of \$10,000 per year, this amount representing the loss previously sustained annually from the corn rootworm. The cotton crop, which formerly in years of bad infestation by the leaf worm was estimated to be injured to the extent of \$30,000,000, is now comparatively free from such injury, owing to the general use of arsenicals.

Facts of like import could be adduced in regard to many other leading staples, but the foregoing are sufficient to emphasize the money value of intelligent action against insect enemies, which may often represent the difference between a profit and a loss in agricultural operations.